DEVELOPING STUDENTS' 21ST CENTURY SKILLS IN STEM MENTOR-MENTEE OUTREACH PROGRAMS

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Abstract

STEM education has increasingly drawn attention internationally in recent years. In Malaysia, efforts to encourage students to take up STEM subjects have risen, but student enrolments in almost every STEM subject area have continued to fall over the last decade. The situation is even more challenging in Sabah, an East Malaysian state where 72 percent of its schools are located in rural areas with basic utilities and limited infrastructures. Therefore, a STEM Mentor-Mentee outreach program through university-school partnership was developed to address the gap in STEM education attainment. The program targeted tenth graders (aged 16 years) from rural secondary schools to help them learn STEM by relating it explicitly to their local environment. STEM activities were guided by the engineering design process while harnessing their 21st century skills. Mentors consisting of in-seervice and pre-service teachers who provided guidance, support and assistance to mentees. Data were captured through mentees' responses to open-ended questions, mentors' field notes, focus group observation and interviews. A total of 732 students, 342 in-service and 99 pre-service teachers were involved in the programs from 2015 to 2019. Findings suggest that the program was able to develop creativity, problem solving, critical thinking and teamwork skills among rural secondary school students.
Keywords: *21st century skills, mentor-mentee, outreach program, rural schools, STEM Education, university-school partnership*

Introduction

STEM (Science, Technology, Engineering, Mathematics) education has been given priority in many countries to produce a young generation that is able to compete in the 21st century. The integration of the disciplines of knowledge consisting of science (Physics, chemistry, and biology) and mathematics with technology and engineering into one field of education is known as STEM Education (Ministry of Science, Technology & Innovation, 2015). In Malaysian Education Development Plan (PPPM) 2013-2025, STEM is mentioned explicitly as a specific initiative to be taken by the Ministry of Education Malaysia (MOE). The initiative is to strengthen STEM education as to produce human capital in the 21st century who have higher order thinking skills, innovative, prudent, independent, technologically literate, able to create, able to solve problems and make decisions (MOE, 2016).

The demand for a STEM driven workforce in Malaysia has become a burgeoning need as the economy has evolved from a production-based economy to a knowledge-based economy. It has been estimated that Malaysia would need 500,000 scientists

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and engineers by 2020 to cope with the challenges of the Fourth Industrial Revolution (Academy of Sciences Malaysia, 2015). However, at that point, it had only 70,000 registered engineers. Undeniably the supply of STEM related workforce is highly dependent on new entrants into STEM related program in upper secondary as well as tertiary level. However, report has shown that only a total of 22.5% of students have enrolled in science stream, and technical and vocational secondary school classes in 2017, which is still far from the ideal ratio of 60:40 Science/Technical: Arts Policy set in 1970 (Academy of Sciences Malaysia, 2018).

The challenge of achieving the 60:40 Science/Technical: Arts Policy is even tougher for the vast rural areas of Malaysia due to its limited infrastructure, lack of good schools and small population (Ling et al., 2015). Sabah, an East Malaysian state with a relatively high proportion of students in rural schools is facing a more challenging situation with respect to its efforts to keep pace with STEM Education. According to the Sabah Economic Development and Investment Authority Blueprint (SDC, 2011), 72% of Sabah's schools were located in rural areas. In terms of infrastructure and basic utilities, most rural primary and secondary schools in Sabah lack supplies of 24-hour electrical connection, access to good teaching and learning resources, computers, and science laboratories. It is apparent that these limited opportunities and facilities have somewhat created a gap in STEM education attainment between rural and urban schools in Sabah and in Malaysia as a whole.

In countries such as Colombia and the United States of America, an outreach program is usually designed to help and encourage disadvantaged students of rural schools to increase their STEM literacy and enthusiasm. These after school STEM outreach programs aim to improve the quality of science education (Laursen et al., 2012), motivate school students to choose STEM subjects in the future, and generate more graduates who have the capacity to pursue science-based careers (Moskal & Skokan, 2011; Office of the Chief Scientist, 2013). While these outreach programs examined the students' STEM literacy and enthusiasm, there is a lack of research examining the program impact on students 21st century skills, thus a gap in the literature that this research will fill.

Brookshire (2014) highlighted the guidance from the right mentor in mentoring can expand students' ideas about the possible careers in STEM fields and trigger a passion for STEM. These observations raised a crucial question: "How would a mentor-mentee outreach program help students in rural secondary schools learn STEM?". Tackling questions like this, particularly in rural settings often requires a more integrated approach to STEM education.

According to Essex (2001), school-college partnerships hold significant promise for renewal and improvement in education (pp. 736). Essex pointed out that successful partnerships allow both the school and the university to work together in an environment in which synergy leads to better decision making, thus having a positive effect on student learning. In this matter, a school-university partnership can help to address the needs of rural schools by providing adequate support and access in the development and delivery of STEM outreach program. Thus, there is a need to adopt an integrated school-university partnership and mentoring approach to produce maximum mutual benefit for all involved in the outreach program, and to seamlessly examine what rural school students would learn during the outreach program. By exposing children to STEM and

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giving them opportunities to explore STEM-related concepts, they will be equipped with 21st century skills such as critical thinking, problem solving, creativity, collaboration, and communication skills as desired by MOE Malaysia (MOE, 2016).

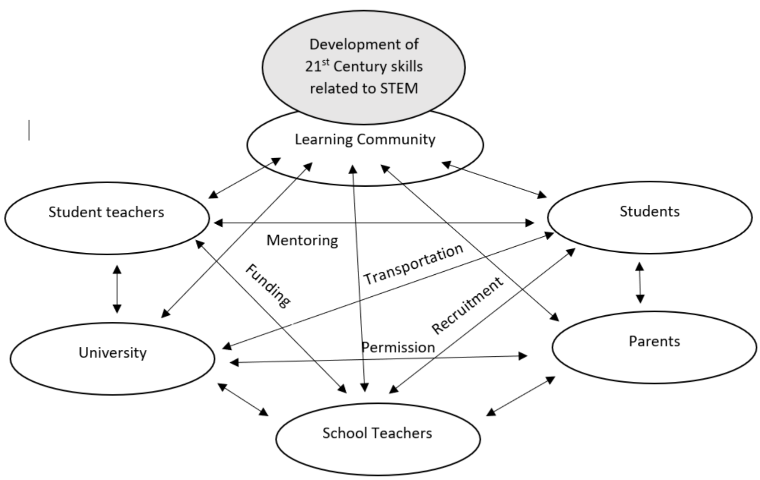
To ensure inclusive and equitable STEM education, a STEM mentor-mentee outreach program through university-school partnership approach has been developed to support disadvantaged and marginalized students in the rural areas. Specifically, this outreach program aims to improve the reach of STEM education in schools geographically distant from the cities of opportunity based on the concept of contextualization and collaboration. This enables rural students to understand STEM by relating it explicitly to their local environment and to increase their 21st Century skills. As such, the objective of STEM mentor-mentee outreach program is to find out if mentor-mentee outreach program would help students in rural secondary schools develop their 21st century skills related to STEM.

The University-School Partnership Model

Bernay (2020) proposed Transformational Learning Community (TLC) model as one form of school–university partnership to address the challenges of the future. The TLC model suggests that the current teaching practices in schools and in universities should be extended into the real world. The purpose is to generate thinking and knowledge creation for children or student teachers to thrive in today's world. Bernay continued to address that learning communities should focus on change; to reinvent schools for transformational learning for children, student teachers, teachers, university lecturers and the wider community. Recognizing the advantages of TLC model to cater to the needs and challenges faced by students in the rural areas, TLC model was adapted in realizing the school–university partnership in the outreach mentor-mentee program. Figure 1 illustrates the range of relationships and resulting benefits in the adapted TLC model.

Figure 1

Transformational Learning Community Model (adapted from Bernay, 2020)



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In order to work in an authentic partnership with rural schools in Sabah, a community of practice was created to draw on the expertise and experience of university science lecturers and student teachers involving in-service and pre-service teachers and co-constructing outreach programs with school teachers, principals and parents. In other words, university Malaysia Sabah (UMS), UMS science lecturer, UMS in-service and pre-service teachers, heads of school science department, school principals and parents were working as a team to carry out the program. The parents granted permission to allow their children to participate during the weekend (Saturday). School principals and heads of science department collaborated to provide the school hall and PA system to be used for the activities. The university provided free bus service to transport the mentors and materials to the schools which are located 16-180 kilometers from Kota Kinabalu, Sabah.

The resources used for running the program were funded by schools and university. The Centre for External Education of the university allocated RM50 to each of its master students to run the program outside the classroom, which was used to support the cost needed to buy materials and equipment. The in-service teachers also sought sponsorship from the local community such as businessmen to support the cost for food and drink for mentees and mentors. The in-service teachers also play their roles in borrowing science apparatus from their school laboratory such as crocodile-clips, hot gun, and glue gun sticks to support the activities. Recycled materials such as plastic bottles, empty boxes, newspapers, and egg trays were collected by mentors which were used as main resources for the activities. Some tools and materials such as scissors, rulers and cutters could be re-used in the followed-up program. Administrative costs were extremely low as free messaging platform such as telegram and WhatsApp were used to ease the communication among people one month prior to the start of the program.

Engineering Design Process Model

The Massachusetts Department of Education (2006, p. 84) proposed eight steps of engineering design process which provide a guide for teachers and curriculum coordinators regarding learning, teaching, and assessment in science and technology/ engineering specific content from Pre-Kindergarten to Grades 6-8 and throughout high school. Those eight steps of engineering design process include identifying the need or problem, research the need or problem, develop possible solution(s), select the best possible solution(s), construct a prototype, test and evaluate the solution(s), communicate the solution(s), and redesign.

Many researchers claim that STEM curricula can be integrated in an engineering design process to provide a mechanism through which students learn relevant STEM content (Hmelo et al., 2000; Mehalik et al., 2008; Schunn, 2009). This mechanism encourages students to make connections, helps connect design failure or next steps to real world engineering and technology (Lottero-Perdue, 2015). Students learn important scientific concepts and their application in engineering and technology, as well as their relationship and application in daily life or real-world context. Students could look for connections by engaging with activities or material in 'real-world' contexts to establish relevance. This approach can attract students’ interest in science lessons and provide them with a deep understanding of concepts and meaningful learning.

Hynes et al. (2011) noted that engineering design process that focus on solutions and construction of prototypes impel students to encounter the process of creative and critical thinking as well as problem solving skills. Hence, engineering design process would offer a route as an instructional framework for fostering 21st century skills among rural secondary school students. According to Mentzer, Huffman and Thayer (2014), engineering design problems embedded in the context of an engineering design process in practice tend to be structurally open-ended and highly complex. Engineering design problems are also designed to be ill-defined. King and Kitchener (1994) characterized ill-defined problems as problems that have no clear-cut right answer and require the integration of many skills and abilities. Solving ill-defined problems requires judgment, planning, the use of strategies, and the implementation of previously learned skill repertoires.

Science teachers in previous program noted several potential challenges while implementing a STEM-project-based learning approach in their rural school classrooms (Siew et al., 2015). These included inadequate materials, limited facilities, and limited allocation of classroom time. Accordingly, the engineering design process employed in this program removed the 'redesign' step proposed by the Massachusetts Department of Education (2006, p. 84). This modification was made to ensure that students could produce workable prototypes that made best use of the materials and time provided in the program.

The Design and Development of STEM Mentor-Mentee Outreach Program

The STEM mentor-mentee outreach program was designed and developed by a science lecturer as program coordinator and assisted by in-service and pre-service teachers. The pre-service teachers were second and third-year undergraduates aged between 22 and 23, training in Physics and Mathematics Education and had no teaching experience in schools. In-service teachers were qualified teachers with degrees in Science and Social Science Education who were undertaking Master course at the time.

Mentor-Mentee. Prior to the program, the faculty recruited mentors among in-service and pre-service teachers, each of whom signs up voluntarily in exchange for experience and competence. Mentors have attended a one-day training course in peer mentoring arranged by the program coordinator. Mentors were trained to conduct facilitation and assessment to their mentees. The mentors were empowered to carry out their role as evaluators and facilitators during the program. After completion of their mentor role, mentors are awarded a Certificate of Contribution by the faculty dean.

The Grade Ten Science Stream students from the secondary rural schools were chosen as the mentees of the program. Mentees received guidance, support and assistance from mentors in finding solutions to problems, using materials, sketching, and building prototypes.

Ill-defined Problem and STEM Activities. The ill-defined problem was introduced to students within the context of their daily life. Students were engaged to connect their daily life experience to solving ill-defined problems. Students would be also asked to consider the constraints of the materials and time, think about what they already know, design, plan, construct, test and evaluate a physical prototype of their design.

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STEM activities were guided by the adapted engineering design process (EDP). The EDP provides a flexible process that takes mentees from identifying a problem, designing a solution to developing, creating, testing and evaluating a prototype to solve daily life problems in their environment using inexpensive materials. It allows students to realize that there are many ways to find solutions, as they engage in brainstorming to identify problems and propose solutions. The process of finding the optimal solution based on constraints requires participants to engage in critical thinking, creativity, imagination, collaboration and communication skills, and problem-solving skills.

Different STEM activities were introduced in each school with local context to enhance learning and understanding of the STEM concepts. A total of three STEM activities were introduced in each school, each taking about three hours and 20 minutes. Examples of ill-defined problems embedded in STEM activities are as follows:

1. “Ali saw a bird perched on a tree branch. A question arose in Abu’s mind, ‘How can it perch for such a long period of time?’

Your task: Create a balancing toy that can stand stably on your fingers like a bird. Each student must produce at least one balancing toy that meets the requirements.

2. “After a year of construction, the Mesilou river bridge that collapsed due to the earthquake has been completed. This news is quite exciting for the villagers who want to cross the Mesilou river. But some are wondering: How much weight can the vehicle support by the bridge? Is it really safe? You and your friends have been given the opportunity to show the villagers that the Mesilou bridge is actually strong enough to support the weight of vehicles crossing it”.

Your task: You and your friend are asked to prove it by designing and building a bridge that crosses a river which is one meter wide. The bridge is strong enough to hold at least 3 cans of coca cola.

Higher-Order Thinking (HOT) Questions. Students also needed to answer the Higher-Order Thinking (HOT) questions that stood of questions that were not strictly in their curriculum. In a way, answering HOT questions inspired students to acquire new found competences. Anderson and Krathwohl (2001)’s Taxonomy was used as a guide to develop a blueprint for the HOT questions, which belonged to the Analysis and Evaluation category of the cognitive domain. Some samples of HOT questions used were: ‘In your opinion, if buildings were constructed identical to this prototype, is it safe to be inhabited? If yes/no, please explain why?’(Evaluation); ‘How can your prototype be modified in order to improve its results in the future?’(Analysis); and ‘Explain why there is a difference of the submarines’ speeds between the two bottles? (Analysis)’. The HOT questions were specially designed to evaluate students’ critical thinking skills in connecting STEM activities with their daily life.

Scoring Rubrics. Scoring rubrics were developed for mentors to evaluate the prototypes produced by the group during the presentation and testing. Aspects assessed were product functionality, sketches, group collaboration, and understanding and application of scientific concepts. Scoring rubrics were constructed based on analytical

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scoring. The quality of student responses and products was assessed from “Poor” (lowest level) to “Very Good” (highest level).

Research Methodology

Research Design

A single group with intervening STEM mentor-mentee outreach program design was used in this research. This was a case study whereby qualitative approach was employed to gain an in-depth knowledge of the participants’ 21st century learning experiences in implementing STEM mentor-mentee outreach program. The Grade Ten Science Stream students (aged 16 years) from the secondary rural schools were chosen as the participants of the research.

Research Instrument

Research instruments included mentors’ field notes and mentees’ responses to open-ended questions; focus group observation and interviews.

Field Notes. Mentors wrote their field notes based on the observation made during the STEM activities, and the semi-structured focus group interviews with mentees. Focus group observations were collected using an observation form adopted from scoring guides developed by Wang et al. (2015). The quality of the students’ responses was ranked from “0” (Level 0: the lowest level) to “3” (Level 3: the highest level). The interview questions were open-ended and the students were encouraged to draw explicitly from their learning experiences of working on the STEM activities. Each focus group interview was conducted in groups consisting of 4-5 mentees after the completion of each STEM activity.

Open-ended Question. A paper-based open question was administered at the end of the program. in view of obtaining written feedback from mentees Students were asked to reflect on their learning experiences following their participation in the STEM mentor-mentee program by responding to the question: ‘Something new I have learned today was…” The open-ended questions offered the mentees an opportunity to clarify, and to fill gaps of missing information not captured by the focus group observations and interviews with mentees.

The Implementation of STEM Mentor-Mentee Program

The program was implemented in 16 rural secondary schools in the districts of Tenom, Tambunan, Ranau, Tuaran, Kota Marudu, Kudat, Penampang, Putatan, Telipok, Sipitang and Kiulu throughout 2015 - 2019. Throughout the five-year program, a total of 732 students, 342 in-service and 99 pre-service teachers were involved in STEM mentor-mentee outreach programs.

In these programs, mentees in group of four or five collaborated to solve an ill-defined problem utilizing the engineering design process. Mentees worked collaboratively to design, build, and test prototypes of their inventions according to the criteria set in an ill-defined problem. Mentees could respond to the ill-defined problems

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in many ways with many different solutions. Mentees also would have opportunities to make use of their STEM knowledge and skills to solve the problem and choose their favorite strategies to obtain their unique solutions. Aspects of science and mathematical concepts and communication skills were also emphasized and evaluated during the presentation of prototypes by group members to their peers and mentors.

Group mentoring involves one or two adult mentors forming a relationship with mentees. The mentors play the role of facilitator and makes a commitment to interact with the mentees over the period of one-day program. The interaction is guided by activity worksheets, which allow time for two ways discussion of the STEM activities.

Data Analysis

Mentors' field notes and mentees' responses to open-ended questions were analyzed using thematic analysis. Thematic analysis is a form of a pattern recognition technique by searching through the data for emerging themes.

Research Results

Solving Daily Life Problems using Scientific Knowledge

Almost every mentee (98%) noted that they benefitted from the STEM activities as they were exposed to real-life situations where scientific knowledge was applied for solving daily life problems. More importantly, STEM activities succeeded in providing a platform for them to apply scientific knowledge in solving problems. Among the scientific concepts the mentees noted were related to water and air pressure, equilibrium of force, base area, balanced force, surface tension, stability, water density and the buoyancy force in a submarine. Mentors from one group confirmed that interviews with mentees revealed that mentees found the need to apply the concept of impulse in order to create an innovation that help to absorb the impact of an egg being dropped from a high place.

Answering Higher Order Thinking (HOT) Questions using Scientific Knowledge

A significant number of mentors (88%) observed that a profound comprehension of scientific knowledge helped participants answer high level questions and to be creative in reapplying knowledge learnt in the designing and producing of prototypes. Mentors observed that HOT questions provide mentees an opportunity to think critically about the answers and make connections with scientific concepts they have learnt in class.

Connecting STEM Activities with Daily Lives and Scientific Concepts Learned

A large percentage (93%) of the mentors noted in their field notes that participants learned how to make connection of the STEM activities with their daily life phenomenon. For example, mentors observed that mentees could relate how ships or boats function and why they could float on the surface of water by making comparisons with their own made boat models. Another example is when answering the HOT questions, mentees could affiliate the floating needle and paper clip activity with the water strider bug,

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a floating log, water lilies, floating ants, and others. Mentors supported these claims by noting that "*Scientific knowledge is not only for answering exam papers but also useful in helping students create connections and explain situations faced in their daily lives. In this case, it is observed that students applied scientific concepts they learned during Physics lessons in problems given to them. Students not only applied the science principles and laws they learnt but also used them in practical forms*".

HOT Questions sparked Critical Thinking

A large percentage (93%) of the mentees expressed through the open questions that they were challenged to think critically when answering the HOT questions in the STEM program. The mentees felt that the HOT questions were difficult, but they tried their best to answer and associate them with their prior knowledge.

According to mentors, mentees were capable of giving rational answers to the HOT questions. For example, one of the group members gave an excellent answer and showed that he/she understood the concept and was able to give a suggestion to improve the existing prototype if given the chance to design it with the aid of extra materials. The sharing of answers added knowledge collectively to the group besides increasing their critical thinking skills. According to mentors, the STEM activities tested and challenged mentees to think outside the box using higher order thinking skills.

Designing and Building Something New and Practical

A large percentage (96%) of the mentees expressed in the open questions that STEM activities gave them an opportunity to create many new, interesting and practical science products using everyday materials. They stated that the balloon powered car made from plastic bottles was a new experience for them. They were fascinated with finding new ways to make a highly powered car moved by air using ever ready materials such as glue, bottles, pencils, and others. Another activity was making a boat. The mentees said they realized that play dough can float when shaped into a boat. Others noted that finding gravity center through making the balancing toys was a new activity. Meanwhile, a few mentees commented that they discovered new ways of floating the needles and paper clips.

When participants were asked why they were excited with the STEM activity, they answered that: "*because we got the chance to design and build a new model which we only see in textbooks*". Other than that, students showed interest in STEM activity because they could become 'designers' of their own boat in the future. Mentors observed that the mentees could design egg protection tools and that every group member worked together the whole time by contributing ideas and carrying out the projects as they had planned. Thus, according to mentors, STEM activity seems to provide a very good start to stimulate the interest of mentees in learning STEM.

Thinking Creatively through Combination of Ideas

A considerably large percentage (78%) of the mentors noted in their field notes that they were amazed when mentees exhibited creativity above anticipations. Group works enhance mentees' ability to produce all kinds of products using limited materials

as a result of the combination of ideas by group members. This can be seen during the construction of the bridge using the newspaper. Many new ideas and views were brought up during brainstorming within the group. With a combination of ideas from group members, they were finally able to build a paper bridge that could be crossed by 3 cans of drinks. Thus, mentors noted that teachers need to acknowledge students' potential and use the right tools and mentorship to enhance their hidden potentials.

Ill-Defined Problems inspired Creativity and Thinking

A significant number of mentors (93%) reported that mentees faced complexities posed by ill-defined problems in the program. These ill-defined problems demanded from them effective response to the challenging tasks which in turn inspired creativity and thinking. For example, the mentees' creativity levels were tested while creating a bottle car that was powered by a balloon. Participants had to figure out ways to move a car by using only air within a balloon, and to think of a method of reducing the car's weight and decrease its tire resistance

Sketching, Designing and Constructing Models fostered Creative Thinking and Problem-Solving Skills

A considerably large percentage (88%) of the mentees expressed opinions that STEM activity encouraged creative thinking, and also problem-solving skills. This was because each activity needed them to sketch and design models according to the creativity of each group. Mentees noted that they had to think of a way to design models that worked and at the same time possessed creative elements. For example, the activity of 'balancing toys' had successfully induced creativity and imagination within mentees as almost every one of them were able to build a balancing toy with different designs. Unexpectedly, mentees in one group were able to create nine balancing toys with different designs. Furthermore, this activity also enhanced mentees' thinking skills. Mentees gained ideas on how to create their own toy design. Hence, it encouraged them to think more profoundly. This was supported by observations made by mentors who noted that: *"Besides creating one 'balancing toy', students can think of ways to merge a few 'balancing toys' in a stable condition"*.

Instilled Thinking through Teamwork

A significant number of mentors (93%) observed that mentees not only came up with some thoughtful ideas but also showed a spirit of teamwork during the STEM activities. Mentors described mutual understanding and cooperation, boosted the confidence of each mentee to do his/her best work in order to construct a workable prototype. Mentees made attempts to cooperate as a group to solve the problems and brainstorming within the group helped mentees to increase their critical and creative thinking. This was proven when a group of five was able to create nine balancing toys with different designs. In another group, group members divided up some tasks such as rolling up a newspaper and stitching together some newspapers in order to produce a paper bridge which in their opinion was a very difficult and challenging activity.

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Solving Problems with a Determined Effort

A large percentage (92%) of the mentors reported that STEM activities challenged the mentees to think of many ideas and make many attempts without giving up. Mentees tested their prototypes through many attempts, improved or modified their original idea through the process of trial-and-error. For example, mentees made modifications to the boat several times so that the boat they built could hold up to 26 marbles. They proved their seriousness in solving the problem despite having to repeatedly test the boat's ability to accommodate large quantities of marbles.

Discussion

The STEM Mentor-Mentee outreach program executed a new idea which addresses a specific challenge of revitalizing STEM movement in rural secondary schools and adds value to rural school students, teachers, and the University. The program used university-school partnership model to reach out to rural schools to improve the 21st century skills and make it more relevant to local context.

Evidence from mentees suggests that the program enabled them to apply STEM knowledge in solving daily life problems, designing and producing daily life products, and answering HOT questions. Mentees were also able to connect the STEM activities with daily lives and scientific concepts learned in the classroom, and to create new products using everyday materials. These findings make clear that the execution of the engineering design process in STEM mentor-mentee outreach program can help mentees in relating and applying STEM knowledge to their daily life problems and contexts. Researchers are in agreement that engineering design process provides a mechanism through which mentees learn to make connections by engaging in 'real-world' problems and contexts (Lottero-Perdue, 2015; Neo, Neo & Tan, 2012).

The STEM mentor-mentee outreach program not only allowed mentees to gain and integrate STEM knowledge but also provided an avenue to boost their creativity, critical thinking, problem solving skills and teamwork. Mentees' creative and critical thinking was sparked through solving HOT questions and ill-defined problems posed in the STEM activities. In addition, as mentees went through the engineering design process such as selecting the best solution in sketching, designing and constructing a prototype have helped them to foster their critical thinking, creative thinking and problem-solving skills. Hence, engineering design process offers a route for mentors to foster 21st century skills among mentees from rural secondary schools. Hynes *et al.* (2011) supported that engineering design process provides students an opportunity to practice critical thinking skills as well as outside-the-box thinking. King and Kitchener (1994) also asserted that exposure to ill-defined problems that mimic those solved by real-world practitioners help students develop problem-solving and critical-thinking skills. This research demonstrates that engineering design process employed in STEM mentor-mentee outreach program allows mentees to focus on solutions to ill-defined problems that could encounter them in the process of creative and critical thinking, and problem-solving skills. The findings of this research suggest that designing ill-defined problem scenarios for the program provide a framework by which mentees can engage in 21st Century skills.

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In this STEM mentor-mentee outreach program, new ideas were generated through the combination of ideas of group members as well as through the trial-and-error method. Mentees as a group respond effectively even with limited materials and time in organizing their thoughts to choose the best possible solution for their prototype using related scientific concepts. Thus, this explains mentees who were actively engaged in collaborative activities could encourage their critical thinking development if mentors guide their critical thinking processes as addressed by *Snyder and Snyder* (2008). This research highlights the important role of mentors to boost the team spirit during the STEM activities.

Similarly, in the STEM activities, students could respond to the ill-defined problems in many ways with many different solutions. Ill-defined problems engage students to make comprehensive use of their STEM knowledge and skills to solve the problem and choose different strategies to obtain their unique solutions. This is in fact a supportive environment in developing many unique responses through teamwork, in line with Sawyer (2003) who stated that people who are engaged in activities together produce a novel outcome. This research highlights that mentees who were engaged in group work during mentor-mentee outreach program were able to generate more novel solutions to a problem, hence promote their creative thinking.

While the mentees described many positive learning experiences gained in this program, they also pointed out several challenges that test their resilience. The most commonly mentioned challenge was the conducted STEM activities required the use of a wide range of cognitive abilities. Mentees tested their prototypes through many attempts, improved or modified their original idea through the process of trial-and-error. This program makes clear that guidance, support and assistance by mentors would clearly help some mentees to complete the prototypes, and thus adequate mentoring from mentors to trigger students' thinking is a critical matter and should be enforced by mentors.

Conclusions

This research provides support for the need of university-school partnerships in making STEM mentor-mentee outreach program a reality in the long run by offering a meaningful way of developing 21st century skills among rural high school students. This research exhibits that many 21st century skills involving high-level cognitive and transferable skills could be inculcated through one STEM mentor-mentee outreach program: problem solving, critical thinking, creativity, communication skills, and teamwork. These are the soft skills essential to be successful in a STEM career.

This research also supports new research examining the potential implementation of STEM outreach programs and university-school partnership in elementary rural schools. Life skills such as entrepreneurial thinking skills can be introduced in the program to examine whether the rural school children could apply these skills in addressing "localized" problems and issues and turning problems into marketable product. Thus, the idea of STEM mentor-mentee outreach program and its activities can be adjusted and fine-tuned by any educators to be researched to new group of students based on the local context**.**

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